Performance Indicators for the Delta

A strategic plan for implementing the new Vision for the California Delta involves 3 interrelated elements: a clear set of goals and objectives; a set of actions for achieving the goals; and agreed measures of performance. This discussion paper focuses on performance measures. However, it is not possible to develop useful performance measures without clear goals and some ideas about what actions will be needed to achieve the goals. The Delta Vision and its Stakeholder group, BDCP, CALFED, and others have provided a lot of material that touches directly or indirectly on goals, objectives, and actions. To set the context for a discussion of performance measures, some ideas about goals and actions from this material will be summarized.

The purpose of this paper is to stimulate discussion. All suggested performance variables are illustrative only.

Goals and Objectives

Delta Vision provided 4 broad goals for a revitalized Delta (www.deltavision.ca.gov/BlueRibbonTaskForce/FinalVision/Delta_Vision_Final.pdf):

1. Continue to provide good quality water for in-Delta and out-of-Delta agriculture and domestic use;
2. Revitalize the Delta ecosystem so that it functions as an estuarine ecosystem delivering goods and services appropriate for such an estuary. Water supply and ecosystem conservation are to be co-equal goals;
3. Sustain the unique attributes of the Delta as a place of individual and cultural significance to the people who live there and;
4. Establish a system of governance and policy making that incorporates the constitutional principles of "reasonable use" and "public trust".

The BDCP has also proposed 5 working biological goals to provide for the conservation and management of listed species and to revitalize Delta ecosystems (http://resources.ca.gov/bdcp/docs/1.25.08_HO_Recommended_GOs.pdf):

1. Restore and maintain viable populations of covered species;
2. Rehabilitate ecosystem processes that support aquatic and adjacent riparian and floodplain natural communities to restore and maintain covered species that rely on those communities;
3. Provide sufficient diversity, quality, and availability of functional habitat to restore and maintain covered species;
4. Manage to an acceptable level of risk the threat of invasion and the adverse effects of non-native species on covered species, ecosystem processes, and habitats that support them;
5. Provide water and sediment quality conditions, including reducing the adverse effects of toxics, sufficient to support ecosystem processes and habitat quality to restore and maintain covered species.

BDCP goals refer specifically to species covered under water export permits and so has a narrower focus than Delta Vision. BDCP goals also refer only to the environmental leg of sustainability. Economy and society are not addressed specifically, although clarifying any limitations on exports to meet the biological goals would have implications for both economy and society. However, the goals do address the revitalization of both species and ecosystem processes so from that perspective they are consistent with the broad ecosystem objectives of Delta Vision.

At its inception, CALFED established four very broad goals represented by its four pillars (reliable water supply, assured water quality, levee integrity, and ecosystem restoration). Only the ecosystem restoration program (ERP) elaborated a set of goals specific to its purposes. These are presented in the Strategic Plan for Ecosystem Restoration (www.delta.dfg.ca.gov/erp/docs/reports_docs/ERPP_Vol_3.pdf):

1. Achieve recovery of at-risk native species and halt or reverse the decline of other native species;

2. Rehabilitate natural processes in the Bay-Delta ecosystem and its watershed to fully support natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native species;

3. Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with the other ERP strategic goals.

4. Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic non-native species (e.g., striped bass, crayfish), communities, ecological processes, recreation, scientific research, and symbolic, or economic value (e.g., salmon, raptors, aesthetics, tules).

5. Prevent the establishment of additional non-native invasive species and reduce the negative ecological and economic impacts of established non-native species in the Bay-Delta estuary and its watershed.

6. Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.

The ERP goals, like those of BDCP, address only environmental aspects of sustainability. Their geographic and ecological scope was broader than that of BDCP, including the watersheds up to the major dams and the ecological community as a whole. However, the basic thrust of BDCP and ERP goals is very similar.

The hierarchy: vision, goals, objectives, actions, is a hierarchy of increasing specificity. Objectives present management needs in more specific form than goals and should point in the direction of specific kinds of actions. Delta Vision, BDCP, and ERP all provided objectives for achieving their ecosystem goals. In Table 1 the ecosystem objectives from Delta Vision, BDCP, and ERP are summarized. The ecosystem objectives from Delta Vision provided the template within which the objectives from BDCP and ERP were organized so that the similarities could be easily seen. Only ERP objectives specific to Delta ecosystems are presented in the table. Although there are some differences (BDCP and ERP included conservation and management objectives whereas Delta Vision does not, for example) there is generally strong agreement among objectives.

A well thought out set of goals and objectives is critical to the strategic planning process. The lists above are primarily for illustration but show that the agencies and other institutions that have considered the problems of the Delta have tended to develop very similar goals and objectives. This suggests a level of agreement that should make it fairly easy to specify the ecosystem goals and objectives for the strategic plan.

Table 1. Comparison of ecosystem objectives summarized from Delta Vision, BDCP, and ERP.

Delta Vision	BDCP	ERP Strategic Plan
Physical Habitat 1. Patterns of freshwater flow that establish variable water conditions and floodplain inundation to benefit native species;	*Physical Habitat* 1. Extent, frequency, and duration of floodplain inundation to provide spawning and rearing habitats and sufficient aquatic productivity for native aquatic organisms;	*Physical Habitat* 1. Hydrologic and hydrodynamic regimes that support the recovery of native species and functional natural habitats, and maintain harvestable species;
2. Channel configurations that are like tentacles and contribute to variable residence time and greater habitat complexity;	2. Increase the diversity and complexity of subtidal habitats and subtidal gradients.	2. Rehabilitate natural processes to create and maintain complex channel morphology, in-channel islands, and shallow water habitat.
3. Tidal access to low lying marginal lands to encourage tidal freshwater and saltwater marsh development;	3A. Connectivity among habitats of covered species to sustain and enhance effective movement and genetic exchange. 3B. Increase the extent, diversity, and complexity of shallow subtidal and intertidal wetland habitats.	3. Establish floodplain inundation and connectivity of a frequency, timing, duration and magnitude to restore functional floodplain, riparian and channel habitats;
4. Patterns of sediment transport, deposition, and erosion that maintain appropriate murky as well as intertidal and shallow sub tidal land forms;		
5. Broad corridors of natural and semi-natural habitats connecting marsh to extensive upland;		5. Minimize the conversion of agricultural land to urban and suburban uses, maintain open space buffers adjacent to existing and future restored habitats, and manage agricultural lands in ways favorable to wildlife.
6. Geometry and topography that allows all life forms expected in a delta-estuary system;	6A. Sufficient extent and quality of spawning and rearing habitats for delta smelt and longfin smelt. 6B. Increase the extent of riparian communities to provide splittail and salmonid habitat.	
7. Marginal land reserves that will allow upslope migration of wetland types in response to sea level rise.		
Stressors 1. Reduced impact of chemical stressors of all types on Delta	*Stressors* 1A. Reduce contaminants entering the Delta to enhance	*Stressors* 1A. Reduce the loadings and concentrations of toxic

species and ecosystems;	aquatic foodweb productivity for covered species. 1B. Reduce contaminants entering the Delta to reduce direct and indirect toxic effects;	contaminants in the Bay-Delta 1B. Reduce the loadings of oxygen depleting substances from human activities into the Bay-Delta.
2. Reduced impact of established non-native species on native species;	2A. Reduce the adverse effects of introduced mollusks and other non-native species on the foodweb throughout the Delta and Suisun Bay. 2B. Reduce the extent of non-native aquatic vegetation to improve conditions for covered species. 2C. Reduce the adverse effects of non-native predators.	2A. Reduce the impact of non-native mammals on native species. 2B. Eradicate or limit the spread of non-native species through focused control measures.
3. Reduced opportunity for invasion of new non-native species;	3A. Reduce the risk of future colonization and establishment of non-native species in the Delta. 3B. Manage habitat areas to control the future colonization and existing abundance of non-native species.	3A. Eliminate introductions of new species from the ballast water of ships into the Bay-Delta. 3B. Halt the unauthorized introduction and spread of potentially harmful non-native species of fish or other aquatic organisms in the Bay-Delta. 3C. Eliminate introductions of new species from imported marine and freshwater baits. 3D. Halt the release of non-native species from private hatcheries or aquaria. 3E. Halt the introduction on non-native aquatic or terrestrial plants into the Delta. 3F. Prevent the invasion of zebra mussels into California.
4. Reduced or eliminated entrainment of desired species and food organisms into water intakes;	4. Reduce the risk of fish entrainment at diversions and pumps	
5. Reduced or eliminated effects of export pumping on flow patterns in the Delta.		
Ecological Process 1. Enhanced processes of food productivity and delivery to valued components of the ecosystem;	*Ecological Process* 1. Hydrodynamic and water quality conditions to support production, quality, and distribution of food supplies for covered fish species.	*Ecological Process* 1. Increase estuarine productivity and rehabilitate food web processes to support recovery and restoration of native species;
2. Restoration and expansion of ecosystems on which rare and threatened species depend;	2. Hydrodynamic and water quality conditions for larval and juvenile downstream transport and spawning adult upstream migration;	2A. Restore large expanses of all major habitat types, and sufficient connectivity among habitats to support recovery of native species and ecological processes. 2B. Enhance and/or conserve

		native biotic communities in the Bay-Delta estuary and its watershed.
3. Enhanced processes that strengthen competitive ability of native species.		
Conservation	*Conservation* 1. Protect existing covered fish species habitat from loss and degradation.	*Conservation* 1A. Protect existing high quality aquatic, wetland, and riparian habitat types and connectivity among habitats for recovery of native species, ecological processes, and public values. 1B. Manage Yolo and Sutter bypasses as major areas of seasonal shallow water habitat for native fish and wildlife,
	2. Manage legal and reduce illegal harvest of Chinook salmon, steelhead, green sturgeon, white sturgeon, and Sacramento splittail.	2A. Enhance fisheries for salmonids, white sturgeon, pacific herring, and native cyprinid fishes. 2B. Maintain fisheries for striped bass, American shad, signal crayfish, grass shrimp, and nonnative warmwater gamefishes. 2C. Enhance populations of waterfowl and upland game for hunting and non-consumptive recreation.
	3. Implement management practices that minimize the ecological, demographic, or genetic effects of hatchery operations on wild Chinook salmon and steelhead.	3. Ensure that chinook salmon, steelhead, trout, and striped bass hatchery, rearing, and planting programs do not have detrimental effects on wild populations of native fish species.
		4. Achieve self-sustaining populations of at-risk native species dependent on the Delta and Suisun Bay.

Performance Measures

Performance measures are essential for effective program and project evaluation (and ultimately policy evaluation as well). They are also an integral part of the adaptive management process. Appropriate performance measures cannot be developed, however, without first deciding on goals and objectives as there must be a direct logical link between the performance measures and particular goals or objectives. There is no universal set of indicators of ecosystem performance. Any assessment of performance is conditional on what society expects from an ecosystem constrained by what it is feasible for the ecosystem to produce.

A number of examples of performance measures for complex and contentious ecosystem and resource management problems exist, both in concept and in practice, that may provide guidance to the Task Force in developing performance measures for its strategic plan. For CALFED, under the Record of Decision, the Science Program and the ISB were responsible for ensuring that the implementing agencies developed and applied appropriate performance measures. To date, the implementing agencies have not seen fit to adopt meaningful programs of performance evaluation. However, the science program, in consultation with the ISB, has developed a framework for performance evaluation that may be useful to the Task Force. The framework reflects input from many different participants both inside and outside of the CALFED agencies.

The framework identifies three general classes of performance measures: administrative indicators; driver indicators; and outcome indicators. The distinction between categories is not rigid. In some cases, an outcome indicator for one purpose may become a driver indicator for another purpose. In greater detail, the 3 classes of indicator are:

1: <u>Administrative indicators</u> describe what resources (funds, programs, projects) are being implemented (or plan to be implemented) for a program or group of related programs. These may also be called "input measures" or "input indicators". Essentially administrative indicators track the money but say nothing about what was actually done or how well it succeeded.

2: <u>Driver indicators</u> describe the factors that may be influencing outcomes. There are two types of driver indicators:

a. <u>Outputs,</u> including on-the-ground implementation of management actions, such as acres of habitat restored or acre-feet of water released, and
b. <u>Uncontrollable factors,</u> which include natural phenomena outside of management control (such as a flood or earthquake) or potentially controllable but not part of the management plan (such as ballast water discharges that introduce new species or levee failure due to poor maintenance).

<u>3. Outcome indicators</u> (also called "response," "ecosystem status or state" or "results" indicators) describe how the ecosystem (or the economy, or society) responds to management actions (Outputs). These are the key indicators of system performance and should be closely related to the goals and objectives of the program.

Table 2 illustrates the different classes of indicator with some specific examples. To illustrate that the outcome of one set of measures could be come an input to another, consider that a decrease in fine sediments entering rivers due to bank stabilization could become an input to improved water quality for salmonids in tributaries.

Although administrative and driver indicators are important for tracking project activity, outcome indicators are the indicators most valuable in assessing program performance. Many different kinds of measurements might provide information on program performance so that selecting an appropriate set of indicators is a challenge. The National Oceanic and Atmospheric

Administration's Coastal Zone Program[1]; conducted an assessment of indicator use in five states in 2002 and reported that practitioners looked for a number of characteristics in indicators:

1. The indicator should be meaningful to external audience;
2. The indicator should be useful for internal management;
3. The indicator should be sensitive to presumed stressors (e.g., progress can be measured on a periodic basis);
4. The indicators within management's scope of control and/or influence;
5. The indicator should represent an outcome rather than an ‘‘output’’;
6. Stakeholders should be involved in an indicator's development;
7. The value of the indicator to management should not exceed its cost;
8. The indicator should be transferable to regional and national ‘‘state of the coast’’ assessment; and
9. Measurement should be consistent in time and space (NOAA, 2002).

Table 2. Examples of administrative, driver and outcome indicators for each of the 4 pillars of CALFED.

	Administrative Indicator	Driver Indicator	Outcome Indicator
Water Supply	# of canal lining projects funded or $ spent on canal lining	miles of canals lined	Acre-feet of water conserved
Water Quality	# of sediment control projects funded or $ spent on sediment control	river miles with stabilized banks	decrease in fine sediments entering rivers
Levees	$ spent in levee repair or maintenance projects	levee miles repaired or upgraded	% decrease in levee failures
Eco-system	$ spent on fish passage projects	# of fish passage barriers removed	increase in fish population in rivers with fish passage barriers removed; increased use of habitat upstream of former barriers

The U.S. EPA has also addressed the problem of choosing appropriate indicators and developed 15 guidelines for evaluating indicators grouped into 4 phases of assessment (Jackson et al., 2000; Barber, 1994):

1. Conceptual relevance - Is the indicator relevant to the assessment question (management concern) and to the ecological resource or function at risk?
2. Feasibility of implementation - Are the methods for sampling and measuring the

[1] NOAA (2002) National Coastal Zone Indicators: An Assessment of Indicator Use and Potential in Five Coastal States. Draft presented at the National Program Managers' Meeting in Silver Spring, MD, March 2002, Washington, DC: NOAA Congressional Requesters, GAO-06-96, October 2005, 92 p

environmental variables technically feasible, appropriate, and efficient for use in a monitoring program?

3. Response variability - Are human errors of measurement and natural variability over time and space sufficiently understood and documented?

4. Interpretation and utility - Will the indicator convey information on ecological condition that is meaningful to environmental decision-making?

Building on the NOAA and EPA analyses, Wardner et al. (2007) and Hershner et al. (2007) devised a framework for performance evaluation that included 5 specific types of indicators:

1. <u>Condition indicators</u> measure status relative to an explicit reference condition. They provide a snapshot of the current state of the system. To be effective, a condition indicator must have an appropriate reference standard and the reference standard must indicate whether the system is in good or poor condition. Managers can assess trends in ecological condition by monitoring condition indicators over time;

2. <u>Evaluation indicators</u> have a clear relationship to a management objective. These are a subset of condition indicators that evaluate the effectiveness of management actions. Evaluation indicators must be responsive to management actions and relevant at the management spatial and temporal scale;

3. <u>Diagnostic indicators</u> are based on an unequivocal dose–response relationship. For the Delta, the correlation between longfin smelt and X2 could be such a relationship. Identification of factors at a multitude of spatial and temporal scales may be required for some indicators. For many management decisions, particularly at larger spatial scales, associations among condition and stressor indicators, rather than dose–response relationships, can be sufficient;

4. <u>Communication indicators</u> are simple and easy to interpret. These indicators encouraging comprehension of condition in its most elementary or integrated form. Examples include the sliding scale assessments provided in the appendix to CALFED's end of stage one report.

5. <u>Futures indicators</u> forecast future conditions based on current information. If suitable models area available, it may be possible to estimate the probable trajectory of condition or the vulnerability of the system to a stochastic event. These indicators are frequently utilized at large spatial and temporal scales. Bay-Delta examples include regional responses to climate change, such as changing hydrology and sea level rise, and seismic risk in the Delta.

The above taxonomy is functional, which should be very useful in a management context. Discussions to date within Delta Vision have suggested a more structural classification that includes physical habitat (5 dimensions listed), ecological process (3 dimensions listed), stressors (5 dimensions listed), resiliency attributes, and viable population attributes. The structural classification is, perhaps, less useful because it does not link intuitively to particular goals and objectives, although this is not precluded by the classification. Stuart Segal has provided a conceptual model of the relationships among these attributes in a recipe for restoration. A portion of his diagrammatic representation of this model is shown below to illustrate these relationships (Figure 2).

In practice, both ways of organizing performance indicators can be used to structure an indicator set (Table 3). Having to satisfy the requirements of each dimension will give some discipline to indicator selection, however, the number of potential indicators will still be larger than needed.

An additional dimension for assisting with indicator selection is the value placed by society on a particular attribute of variable. Through stakeholder dialogue and problem scoping, variables that best capture aspects of the system that are valued by society and have meaning in the context of local knowledge can be determined and used to help narrow the list of indicators. Indicators that pass this test of being socially valued will also fit well into the communication class.

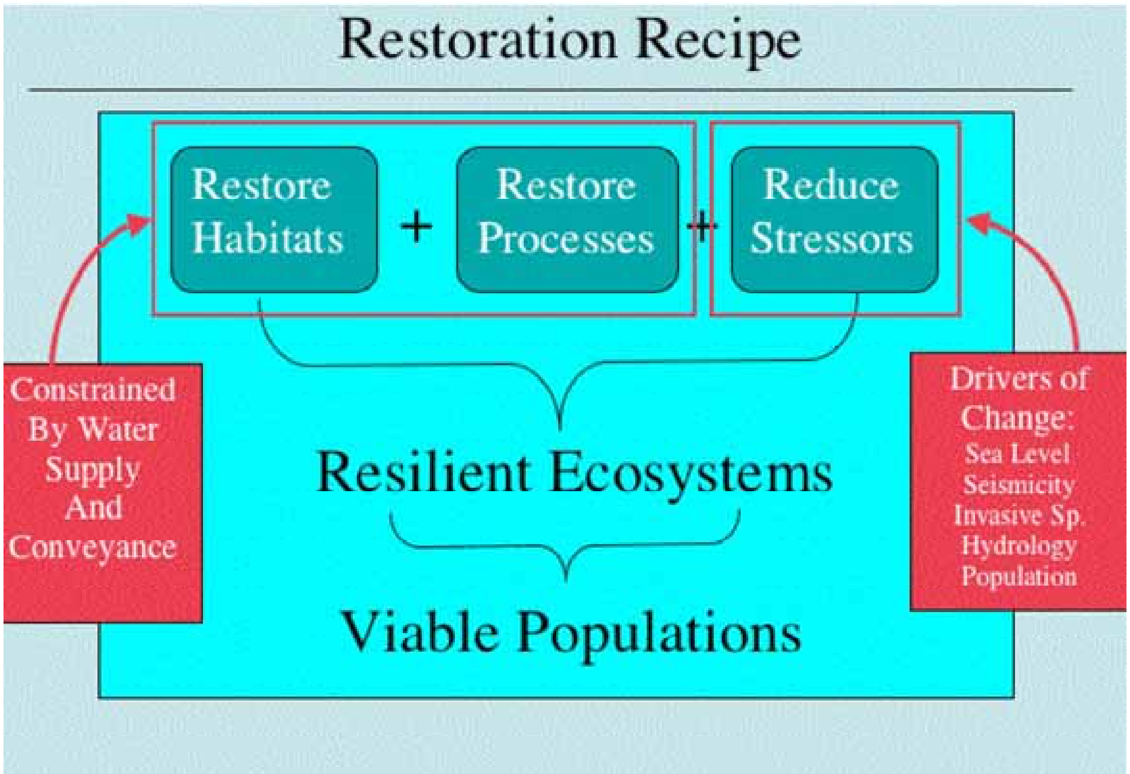

Figure 1. A model of restoration showing relationships between habitats, ecological processes, stressors, ecosystem resiliency and population viability. Adapted from Stuart Segal's discussion paper, " Ecosystem (Response) Performance Measures, Delta Vision Strategic Plan: First Thoughts for Developing" (2/6/08).

Table 3. Matrix of illustrative indicators for the Delta ecosystem arranged in relation to functional and structural indicator classes taken from Wardner et al. (2007), Hershner et al. (2007) and Delta Vision discussions.

Structural Types (from Delta Vision)	Functional Groups of Indicators (from Wardner et al. 2007, and Hershner et al. 2007)				
	Condition	Evaluation	Diagnostic	Communication	Futures
Habitat	Water residence time, mosaic of land use types	Salinity, dissolved oxygen	X2, wetland acres	TMDL	Climate change variables

Process	Primary production, erosion/deposition	Bioaccumulation of toxic chemicals	Returns per spawner, energy flow pathways	Fish harvest	Rates of species introduction
Stressor	Turbidity, export ratios	Mercury concentration	Selenium concentration	Toxicity levels in fish	Changes in loading
Resilience	Biodiversity?	Number of listed species?	?	Regime change?	?
Viable Pop'n	Numerical abundance	Rate of change in abundance	Direction of change in abundance	Population viability index	Environmental tolerance variables

An important aspect of performance evaluation not addressed well in the examples and matrices above is the scale at which measurements and evaluations should be made. The Delta is a complex environment. It is also a component of a much larger landscape system and is greatly influenced by events that happen in the watersheds upstream, in the coastal ocean, and in the atmosphere. Performance evaluation at the scale of the watershed or coastal ocean will necessarily be coarse grained and will not capture much of the detail of the Delta. Even at the scale of the Delta, locally significant features may be missed. Performance evaluation may, therefore, have to be measured at a number of scales. It will be helpful if measurements are compatible across scales so that local measurements can be aggregated to give a larger picture. This will probably not be possible for some kinds of variables but should be considered whenever variables are being evaluated. Time scales of performance evaluation are equally important. There is a general relationship between geographic and time scales in that larger geographic scales tend to change over longer time periods. This is not a universal rule, however, as large scale variables can sometimes change relatively rapidly, especially if they are subject to human manipulation (land cover, for example).

A further critical aspect of performance evaluation stressed by Wardner et al. (2007) is establishing benchmarks for performance variables. In some cases, historic values may be a useful guide. However, in highly modified ecosystems like the Delta, historic conditions can never be recreated. In such circumstances, the capacity of the modified system to support particular species or to generate particular services must provide the necessary guidance. In some instances it may have to be acknowledged that the current context cannot support certain historic ecological services. Invariably there will be trade-offs among competing uses of environmental services (e.g., water for agriculture, water for ecosystem; land for wetland, land for urban) and how these trade-offs are decided will impact on the capacity of the system to sustain particular services. Conceptual and numerical models of system dynamics will be important in establishing what is feasible given the current state of the system. The conceptual models developed through DRERIP should provide a useful starting point for the necessary analyses. These models should also be a rich source of potential performance indicator variables.

As noted earlier, this discussion paper addresses approaches to ecosystem assessment. For sustainability, both economic and social assessment is also required. There are many well established approaches to economic assessment. The difficulty has always been integrating ecosystem and economic objectives and evaluation since most ecological services are not traded in a market place so there is no straightforward way to set prices. Social evaluation can be even more contentious from a sustainability perspective. Nevertheless, these issues will have to be addressed in the strategic plan.

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